Section 2

Air Pressure

Objectives

After this lesson, students will be able to

I.1.2.1 Identify some properties of air.

I.1.2.2 Name instruments that are used to measure air pressure.

I.1.2.3 Explain how increasing altitude affects air pressure and density.

Target Reading Skill

Identifying Main Ideas Explain that identifying main ideas and details helps students sort facts from the information into groups. Each group can have a main topic, subtopics, and details.

Answers

Possible answers include the following:
Main Idea: Because air has mass, it also has density and pressure.
Detail: Density is the amount of mass of a substance in a given volume.
Detail: Pressure is the force pushing on an area or surface.

All in One Teaching Resources

- Transparency I3

Preteach

Build Background Knowledge

L1

Changes in Air Pressure

Ask: **Did your ears ever "pop" when you rode in an elevator or airplane?** *(Many students probably have had this experience.)* Explain that as you go higher, the pressure of the air outside the body decreases while the pressure of the air inside the body, including inside the ears, stays the same. The popping sensation is air escaping from inside the ears into the throat to even out the pressure. Tell students they will learn more about air pressure and other properties of air in this section.

Air Pressure

Reading Preview

Key Concepts

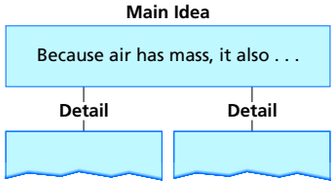
- What are some of the properties of air?
- What instruments are used to measure air pressure?
- How does increasing altitude affect air pressure and density?

Key Terms

- density
- pressure
- air pressure
- barometer
- mercury barometer
- aneroid barometer
- altitude

Target Reading Skill

Identifying Main Ideas As you read the Properties of Air section, write the main idea—the biggest or most important idea—in a graphic organizer like the one below. Then write two supporting details. The supporting details give examples of the main idea.



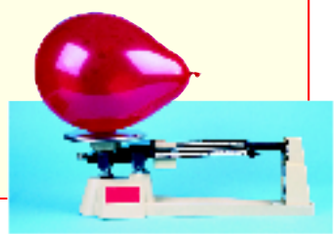
Lab zone Discover Activity

Does Air Have Mass?

1. Use a balance to find the mass of a deflated balloon.
2. Blow up the balloon and tie the neck closed. Predict whether the mass of the balloon plus the air you have compressed into it will differ from the mass of the deflated balloon.
3. Find the mass of the inflated balloon. Compare this to the mass of the deflated balloon. Was your prediction correct?

Think It Over

Drawing Conclusions What can you conclude about whether air has mass? Explain your conclusion.



The air is cool and clear—just perfect for an overnight hiking trip. You've stuffed your backpack with your tent, sleeping bag, stove, and food. When you hoist your pack onto your back, its weight presses into your shoulders. That pack sure is heavy! By the end of the day, you'll be glad to take it off and get rid of all that weight.

But here's a surprise: Even when you take off your pack, your shoulders will still have pressure on them. The weight of the atmosphere itself is constantly pressing on your body.

Like a heavy backpack pressing on your shoulders, the weight of the atmosphere causes air pressure.

Lab zone Discover Activity

Skills Focus Drawing conclusions

Materials balance, balloon

Time 10 minutes

Tips You may want to review how to use the balance before students begin the activity. The larger the balloon, the greater the difference in mass will be. Inflatable balls may be substituted for balloons.

L1

Expected Outcome The balloon should have a greater mass after it is inflated.

Think It Over The mass of the balloon increased after it was inflated, leading students to conclude that air has mass.

Properties of Air

It may seem to you that air has no mass. But in fact, air consists of atoms and molecules, which have mass. So air must have mass. **Because air has mass, it also has other properties, including density and pressure.**

Density The amount of mass in a given volume of air is its **density.** You can calculate the density of a substance by dividing its mass by its volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

If there are more molecules in a given volume, the density is greater. If there are fewer molecules, the density is less.

Pressure The force pushing on an area or surface is known as **pressure.** The weight of the atmosphere exerts a force on surfaces. **Air pressure** is the result of the weight of a column of air pushing down on an area. The column of air extends upward through the entire atmosphere, as shown in Figure 4.

The atmosphere is heavy. The weight of the column of air above your desk is about the same as the weight of a large schoolbus. So why doesn't air pressure crush your desk? The reason is that the molecules in air push in all directions—down, up, and sideways. The air pushing down on top of your desk is balanced by the air pushing up on the bottom of your desk.

Air pressure can change from day to day. A denser substance has more mass per unit volume than a less dense one. So denser air exerts more pressure than less dense air.

Reading Checkpoint **How does the density of air affect air pressure?**

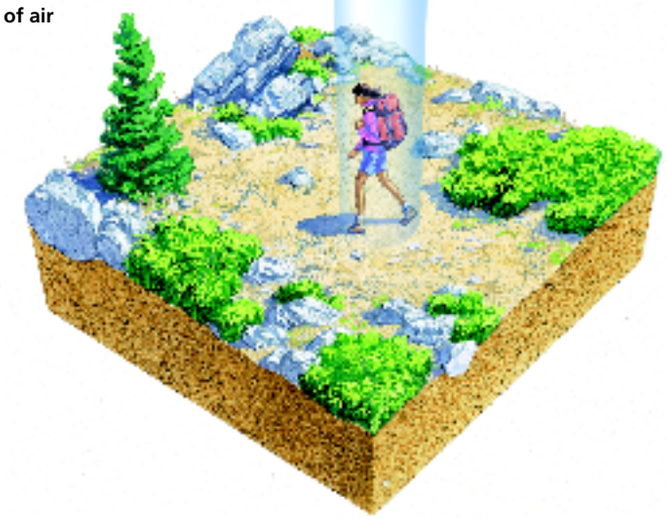


FIGURE 4
Air Pressure
There is a column of air above you all the time. The weight of the air in the atmosphere causes air pressure.

Instruct

Properties of Air

Teach Key Concepts L2

Density and Air Pressure

Focus Review the difference between mass and weight. (Mass is the amount of matter in an object; weight is a measure of how much gravity pulls on an object—its heaviness.)

Teach Ask: **How are mass and density related?** *(If there is more mass in a given volume of air, then the density is greater.)* **How are mass and air pressure related?** *(If there is more mass in a given volume of air, then it will exert greater air pressure.)* Ask students to look at Figure 4, and have a volunteer read the caption.

Apply Match and squeeze the ends of two sink plungers together. Invite two volunteers to try to pull the plungers apart. Ask: **Why are the plungers hard to pull apart?** *(Air is pressing on the outside of the plungers and holding them together. There is less air pressure inside the plungers.)* **learning modality: visual**

Independent Practice L2

All in One **Teaching Resources**

- Guided Reading and Study Worksheet: *Air Pressure*

Student Edition on Audio CD

Differentiated Instruction

Special Needs L1

Understanding Density Mark off two six by six square unit areas on the floor with meter sticks or other flat items, or masking tape if permitted by your school. Ask several volunteers to stand in one square. Have several more volunteers stand in the second square so that they are close, but not touching. Ask students to imagine that they are molecules of air inside two hot air balloons. Ask: **Which "balloon" is denser? How do you know?** *(The "balloon" with more students is denser because there are more "molecules" in the same amount of space as the other "balloon.")* **learning modality: kinesthetic**

Monitor Progress L2

Oral Presentation Ask students to describe the major differences between density and air pressure.

Answer

Reading Checkpoint Denser air exerts more air pressure than less dense air.

Go Online active art

For: Measuring air pressure activity
Visit: PHSchool.com
Web Code: cfp-0412

Students can interact with the art of a mercury barometer online.

Measuring Air Pressure

Teach Key Concepts L2

How Barometers Work

Focus Remind students that air pressure is the result of a column of weight pushing down on an area and can be measured with instruments.

Teach Ask: **Why must there be a near vacuum in the tube of the mercury barometer?** *(So that there is little air pressure inside the tube and the mercury can rise inside the tube)* **What is the main difference between the types of barometers?** *(Mercury barometers use a liquid to indicate changes in air pressure; aneroid barometers do not.)*

Apply Tell students that by using barometric measurements, meteorologists are able to predict weather patterns. High pressure readings often indicate little or no precipitation, and low pressure readings often indicate high amounts of precipitation. **learning modality: logical/mathematical**

Use Visuals: Figures 5 and 6 L1

Types of Barometers

Focus Have a student volunteer read the captions for Figures 5 and 6.

Teach Ask students to describe how changes in air pressure affect each barometer. *(In one, mercury rises or falls in a column; in the other, the chamber walls flex in and out, moving a needle on a dial.)* Ask: **What would an increase in the number on the dial of an aneroid barometer indicate?** *(Air pressure is rising.)* **How is this indicated in a mercury barometer?** *(The mercury in the tube rises.)*

Apply Ask: **How are barometers useful to meteorologists?** *(Barometers show changes in air pressure that meteorologists can use to predict changes in weather.)* **learning modality: visual**

Lab zone Try This Activity

Soda-Bottle Barometer

Here's how to build a device that shows changes in air pressure.

1. Fill a 2-liter soda bottle one-half full with water.
2. Lower a long straw into the bottle so that the end of the straw is in the water. Seal the mouth of the bottle around the straw with modeling clay.
3. Squeeze the sides of the bottle. What happens to the level of the water in the straw?
4. Let go of the sides of the bottle. Watch the level of the water in the straw.

Inferring Explain your results in terms of air pressure.

Measuring Air Pressure

A **barometer** (buh RAHM uh tur) is an instrument that is used to measure air pressure. **Two common kinds of barometers are mercury barometers and aneroid barometers.**

Mercury Barometers Figure 5 shows the way a mercury barometer works. A **mercury barometer** consists of a glass tube open at the bottom end and partially filled with mercury. The space in the tube above the mercury is almost a vacuum—it contains very little air. The open end of the tube rests in a dish of mercury. The air pressure pushing down on the surface of the mercury in the dish is equal to the pressure exerted by the weight of the column of mercury in the tube. When the air pressure increases, it presses down more on the surface of the mercury. Greater air pressure forces the column of mercury higher. At sea level the mercury column is about 76 centimeters high, on average.

Aneroid Barometers If you have a barometer at home, it is probably an aneroid barometer. The word aneroid means "without liquid." An **aneroid barometer** (AN uh royd) has an airtight metal chamber, as shown in Figure 6. The metal chamber is sensitive to changes in air pressure. When air pressure increases, the thin walls of the chamber are pushed in. When the pressure drops, the walls bulge out. The chamber is connected to a dial by a series of springs and levers. As the shape of the chamber changes, the needle on the dial moves.

Go Online active art

For: Measuring Air Pressure activity
Visit: PHSchool.com
Web Code: cfp-4012

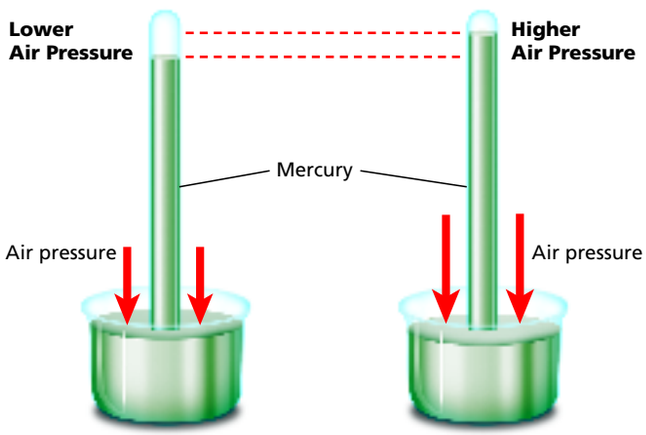


FIGURE 5
Mercury Barometer
Air pressure pushes down on the surface of the mercury in the dish, causing the mercury in the tube to rise. The air pressure is greater on the barometer on the right, so the mercury is higher in the tube.
Predicting *What happens to the level of mercury in the tube when the air pressure decreases?*

Lab zone Try This Activity

Skills Focus Inferring L2

Materials 2-liter soda bottle, long straw, modeling clay, water

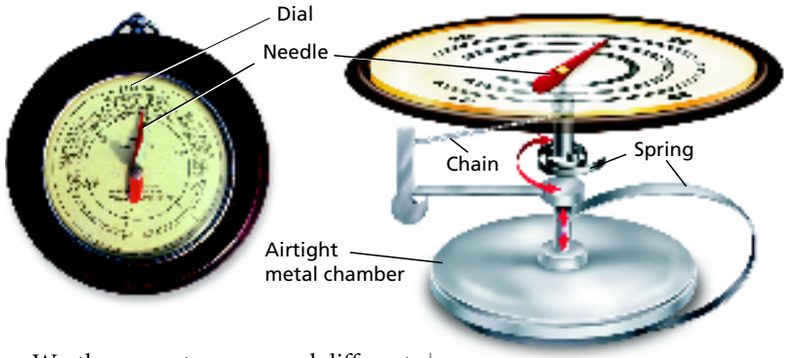
Time 10 minutes

Tips Before students seal the mouth of the bottle with clay, make sure the straw is in the water but not touching the bottom of the bottle.

Expected Outcome When students squeeze the bottle, the water level rises in the straw. Water rises in the straw because air pressure in the bottle increases.

Extend Students can explore whether heating or cooling the air in the bottle would affect the water level in the straw. **learning modality: logical/mathematical**

FIGURE 6
Aneroid Barometer
This diagram shows an aneroid barometer. Changes in air pressure cause the walls of the airtight metal chamber to flex in and out. The needle on the dial indicates the air pressure.



Units of Air Pressure Weather reports use several different units for air pressure. Most weather reports for the general public use inches of mercury. For example, if the column of mercury in a mercury barometer is 30 inches high, the air pressure is "30 inches of mercury" or just "30 inches."

National Weather Service maps indicate air pressure in millibars. One inch of mercury is approximately 33.87 millibars, so 30 inches of mercury is approximately equal to 1,016 millibars.

Reading Checkpoint **What are two common units that are used to measure air pressure?**

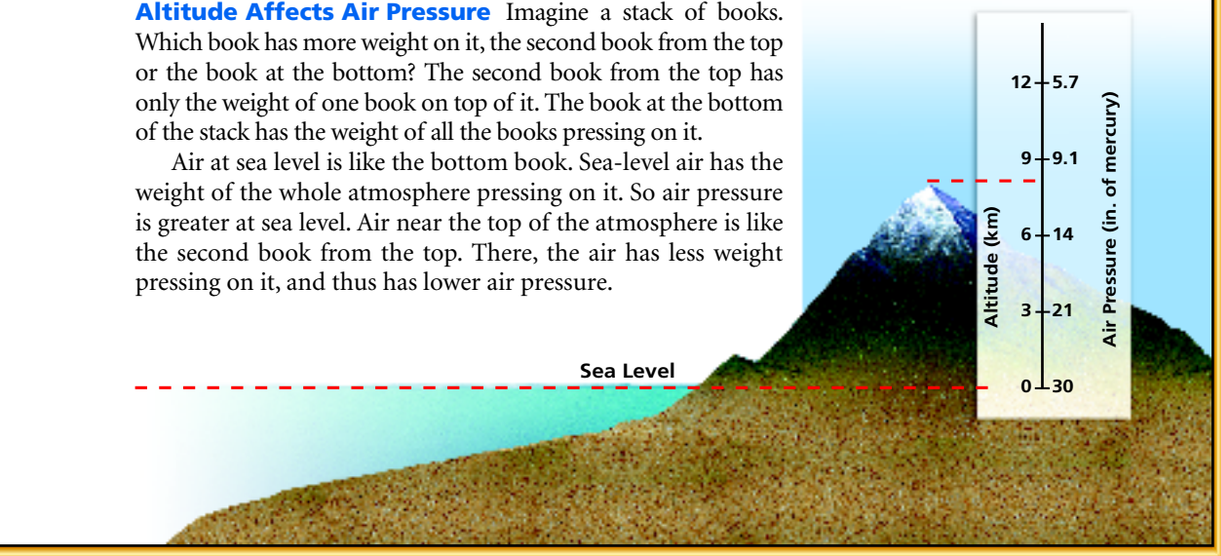
Altitude and the Properties of Air

At the top of a mountain, the air pressure is less than the air pressure at sea level. **Altitude,** or elevation, is the distance above sea level, the average level of the surface of the oceans. **Air pressure decreases as altitude increases. As air pressure decreases, so does density.**

Altitude Affects Air Pressure Imagine a stack of books. Which book has more weight on it, the second book from the top or the book at the bottom? The second book from the top has only the weight of one book on top of it. The book at the bottom of the stack has the weight of all the books pressing on it.

Air at sea level is like the bottom book. Sea-level air has the weight of the whole atmosphere pressing on it. So air pressure is greater at sea level. Air near the top of the atmosphere is like the second book from the top. There, the air has less weight pressing on it, and thus has lower air pressure.

FIGURE 7
Air Pressure and Altitude
Air pressure is greater at sea level and decreases as the altitude increases.



Differentiated Instruction

Gifted and Talented L3
Calculating Air Pressure Tell students that if you laid a quarter on a table, it would exert a pressure of 0.00013 kg per cm^2. Then say that the pressure exerted by the atmosphere at sea level is 1.03 kg per cm^2. Ask: **How many quarters would you need to stack on top of one another for the quarters to exert the same pressure as the air at sea level?** *(1.03 kg ÷ 0.00013 kg = 7,923 quarters)* **If six quarters are about 1 cm thick, how high would the stack of quarters be?** *(7,923 ÷ 6 = 1,321 cm or about 1.3 km)* **learning modality: logical/mathematical**

Lab zone Build Inquiry L2

Predicting Weather Patterns

Materials copies of newspaper weather reports for several consecutive days

Time 15 minutes

Focus Remind students that weather reports for the public use inches of mercury.

Teach Explain that the average air pressure worldwide is 29.92 inches. A drop of less than an inch can signal a major storm; a rise of less than an inch can signal fair weather. Have students examine the weather reports to observe how changes in barometric pressure are related to weather conditions.

Apply Have students use the daily local forecast to predict the weather for the coming days. **learning modality: logical/mathematical**

Altitude and the Properties of Air

Teach Key Concepts L1

Increasing Altitudes

Focus Remind students that air has weight.

Teach Ask: **What is the relationship between altitude and air pressure?** *(Air pressure decreases as altitude increases.)* **Why is air pressure greater at sea level?** *(Sea-level air has the weight of the whole atmosphere pressing on it.)* **Is density higher or lower at high altitudes?** *(Lower, because the air is thinner)*

Apply Display a physical map of the world, and ask students to indicate areas of high and low air pressure. *(Areas with the highest altitudes, such as mountain ranges, normally have the lowest air pressure. Areas at or below sea level normally have the highest air pressure.)* **learning modality: visual**

All in One **Teaching Resources**
- Transparencies I4, I5

Monitor Progress L2

Skills Check Have students make a table comparing and contrasting mercury barometers and aneroid barometers.

Answers
Figure 5 It falls.

Reading Checkpoint Millibars and inches of mercury

The Atmosphere

Show the Video Field Trip to help students understand how atmospheric conditions change with altiutde. Discussion question: **As altitude increases, what happens to air pressure?** *(It decreases.)*

Integrating Life Science L2

People who live at high altitudes have developed adaptations to the low pressure and density of oxygen in the air around them. Ask: **What kinds of adaptations would allow people to live successfully at high altitudes?** *(A larger chest and lungs would allow a person to take in more air.)*
learning modality: logical/mathematical

Monitor Progress L2

Answer

Reading Checkpoint Air is less dense; therefore, each breath takes in fewer oxygen molecules at a higher altitude than at sea level.

Assess

Reviewing Key Concepts

1. a. The result of the weight of a column of air pushing down on an area **b.** Its pressure increases.
2. a. Mercury barometer and aneroid barometer **b.** Millibars or inches of mercury **c.** 922.3 millibars
3. a. Height above sea level **b.** Air pressure decreases; density decreases. **c.** Air pressure would increase. The amount of air above you would increase as you go downward, thus increasing the "weight," or pressure, of the air above you.

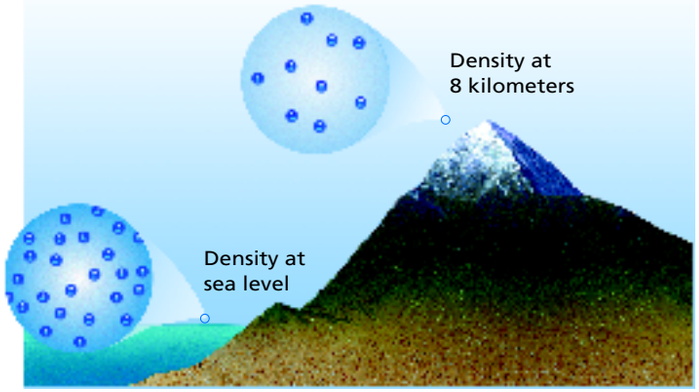
Reteach L1

Sketch an ocean and a mountain on the board. Ask students to describe the differences in air pressure and density for both locations as you indicate them.

All in One Teaching Resources

- Section Summary: *Air Pressure*
- Review and Reinforce: *Air Pressure*
- Enrich: *Air Pressure*

FIGURE 8
Altitude and Density
The density of air decreases as altitude increases. Air at sea level has more gas molecules in each cubic meter than air at the top of a mountain.



Altitude Also Affects Density As you go up through the atmosphere, the density of the air decreases. This means the gas molecules that make up the atmosphere are farther apart at high altitudes than they are at sea level. If you were near the top of a tall mountain and tried to run, you would quickly get out of breath. Why? The air contains 21 percent oxygen, whether you are at sea level or on top of a mountain. However, since the air is less dense at a high altitude, there are fewer oxygen molecules to breathe in each cubic meter of air than at sea level. So you would become short of breath quickly at high altitudes.

Reading Checkpoint **Why is it hard to breathe at the top of a mountain?**

Section 2 Assessment

Target Reading Skill **Identifying Main Ideas** Use your graphic organizer to help you answer Question 1 below.

Reviewing Key Concepts

1. a. **Defining** What is air pressure?
b. **Explaining** How does increasing the density of a gas affect its pressure?
2. a. **Listing** What two instruments are commonly used to measure air pressure?
b. **Measuring** What units are commonly used to measure air pressure?
c. **Calculating** How many millibars are equal to 27.23 inches of mercury?
3. a. **Defining** What is altitude?
b. **Relating Cause and Effect** As altitude increases, how does air pressure change? How does density change?
c. **Predicting** What changes in air pressure would you expect if you carried a barometer down a mine shaft?

Lab zone At-Home Activity

Model Air Pressure Here's how you can show your family that air has pressure. Fill a glass with water. Place a piece of cardboard over the top of the glass. Hold the cardboard in place with one hand as you turn the glass upside down. **CAUTION:** *Be sure the cardboard does not bend.* Now remove your hand from the cardboard. What happens? Explain to your family that the cardboard doesn't fall because the air pressure pushing up on it is greater than the weight of the water pushing down.

Lab zone At-Home Activity

Model Air Pressure L1 Tell students to make sure that they fill the glass until the level of water bulges over the rim and to make sure that the cardboard does not bend. Advise them not to let any air bubbles under the cardboard and to do the activity over a sink, as some water may overflow the glass.

Lab zone Skills Lab

Working Under Pressure

Problem

How can a barometer detect changes in air pressure?

Skills Focus

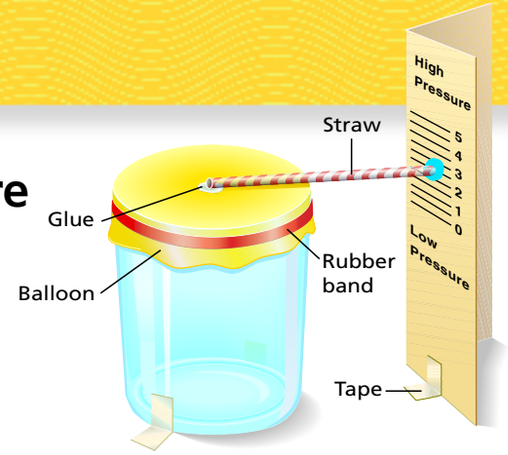
interpreting data, drawing conclusions

Materials

- modeling clay
- scissors
- white glue
- tape
- pencil
- wide-mouthed glass jar
- metric ruler
- cardboard strip, 10 cm × 25 cm
- rubber band
- large rubber balloon
- drinking straw, 12–15 cm long

Procedure

1. Cut off the narrow opening of the balloon.
2. Fold the edges of the balloon outward. Carefully stretch the balloon over the open end of the glass jar. Use a rubber band to hold the balloon on the rim of the glass jar.
3. Place a small amount of glue on the center of the balloon top. Attach one end of the straw to the glue. Allow the other end to extend several centimeters beyond the edge of the glass jar. This is your pointer.
4. While the glue dries, fold the cardboard strip lengthwise and draw a scale along the edge with marks 0.5 cm apart. Write "High pressure" at the top of your scale and "Low pressure" at the bottom.
5. After the glue dries, add a pea-sized piece of modeling clay to the end of the pointer. Place your barometer and its scale in a location that is as free from temperature changes as possible. Note that the pointer of the straw must just reach the cardboard strip, as shown in the diagram.
6. Tape both the scale and the barometer to a surface so they do not move during your experiment.



7. Make a data table like the one below in your notebook. Record the date and time. Note the level of the straw on the cardboard strip.

Data Table		
Date and Time	Air Pressure	Weather Conditions

8. Check the barometer twice a day. Record your observations in your data table.
9. Record the weather conditions for at least three days.

Analyze and Conclude

1. **Interpreting Data** What change in atmospheric conditions must occur to cause the free end of the straw to rise? What change must occur for it to fall?
2. **Drawing Conclusions** Based on your observations, what kind of weather is usually associated with high air pressure? With low air pressure?
3. **Communicating** Write a paragraph in which you discuss what effect, if any, a large temperature change might have on the accuracy of your barometer.

More to Explore

Compare your pressure readings with high and low pressure readings shown in newspaper weather maps for the same period. How do your readings compare with those in the newspaper?

Sample Data Table		
Date and Time	**Air Pressure**	**Weather Conditions**
April 2, 10 A.M.	1	rainy, 24° C
April 2, 2 P.M.	2	cloudy, 23° C
April 4, 10 A.M.	4	sunny, 18° C
April 4, 2 P.M.	5	sunny, 19° C

Analyze and Conclude

1. Air pressure must rise; air pressure must fall.
2. Clear, dry weather; cloudy, wet, or stormy weather
3. Paragraphs should include that a great increase in temperature would cause the air inside the barometer to expand and a large decrease in temperature would cause it to contract, affecting the readings.

Lab zone Skills Lab

Working Under Pressure

L2

Prepare for Inquiry

Skills Objectives

Students will be able to

- interpret data for the kinds of weather conditions that are associated with high and low air pressure
- draw conclusions about the effect of a large temperature change on the accuracy of their barometers

Prep Time 15 minutes
Class Time 40 minutes for the first day; 10 minutes each day for the next two days

Safety

Remind students to use caution when working with scissors and glass. Review the guidelines in Appendix A.

All in One Teaching Resources

- Lab Worksheet: *Working Under Pressure*

Guide Inquiry

Troubleshooting the Experiment

- Before students cut their balloon, suggest they inflate it to stretch the rubber.
- Once the balloon is in place, students should make sure that it does not leak air.

Expected Outcome

When air pressure outside is low, the higher air pressure inside the jar pushes up on the balloon, causing the pointer to fall. The opposite occurs when air pressure outside is high.

Extend Inquiry

More to Explore Students' air pressure readings should agree in general with those in the newspaper. If readings do not agree, balloons may be leaking air or may not be stretchy enough, or the lumps of clay may be too large. Students' barometers are not likely to be accurate enough to reflect minor fluctuations in air pressure.